ARBITRARILY WIDE-ANGLE WAVE EQUATIONS AND THEIR APPLICATION TO SUBSURFACE IMAGING AND SEISMIC MIGRATION

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Figure 1. First order (15°) image of a crack in a media with continuously varying velocity.

Detecting structural and material characteristics in the subsurface is important in many disciplines ranging from nondestructive evaluation to geophysical exploration. In many cases, waves are used to image the subsurface by analyzing the reflections from hidden events or flaws. The transformation from the measured data at the surface (surface trace) into an image of the subsurface is called migration or synthetic focusing in the context of geophysics and NDE respectively. Many techniques have been proposed and used to perform migration. However, many of the existing methods either require prohibitively expensive computations, or result in significant errors in the resulting image. With the aim of obtaining an economical method that results in clear (accurate) images of the subsurface, the authors have developed an alternative approach in an existing class of migration methods, namely the one-way wave equation (OWWE) or Parabolic Equation (PE's) methods.

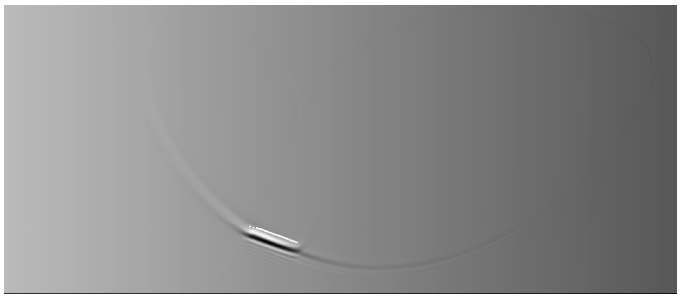

Figure 2. Fourth-order (1 Auxiliary variable) AWWE image of a crack in a media with continuously varying velocity.

OWWE-based methods are one of the most common tools used in migration process. However, the OWWE in its exact form cannot be practically formulated and solved in time-space domain. The time-space formulation can be made possible by approximating the square root operator in the frequency-wave number domain. Conventional high-order approximations of OWWE can result in more accurate images, but contain high-order derivatives that cause problems in terms of economy, accuracy and stability of the numerical implementation. A number of methods have been proposed to achieve higher-order accuracy without dealing with higher-order terms.

In our alternate approach, we have developed ARBITRARY WIDE-ANGLE WAVE EQUATIONS (AWWE) that are high-order approximations of OWWE without high-order derivatives. Starting from continued fraction approximation of the square-root operator, and by using auxiliary variables, AWWE takes the form of a system of second-order PDEs. Hence the process of increasing the accuracy of the imaging process reduces to adding auxiliary variables, as opposed to adding a higher-order terms (Figures 1 and 2 show the imaging result in a heterogeneous domain for the lowest order formulation and AWWE with one auxiliary variable). A stable explicit scheme is designed for numerical implementation of AWWE. As a result, the computational expense of the proposed technique is significantly less than that of the existing migration methods that are mostly implicit. This reduction in computational cost facilitates high accuracy imaging using reasonable computational effort. Furthermore, the proposed AWWE is designed to image events in strongly heterogeneous media, and appears to be extendible to elastic (multi-component) imaging problems. In this talk, the formulation and implementation of AWWE would be discussed along with numerical examples illustrating the effectiveness of the method.